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OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAM

FOR THE

STANFORD UNIVERSITY MEETING

AT

STANFORD UNIVERSITY, California

DECEMBER 17–18, 1937

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BULLETIN

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STANFORD UNIVERSITY MEETING

THE 217th regular meeting of the American Physical Society will be held at Stanford University, California, in the physics department, room 372, on Friday, December 17 and Saturday, December 18, 1937. Morning sessions will be held on both days, starting at 9:30 o'clock, and an afternoon session will be held Friday, starting at 1:30 o'clock.

Indianapolis Meeting. The preliminary arrangements of the Indianapolis program include a joint session on Tuesday, December 28, with Section B of the American Association for the Advancement of Science and the American Association of Physics Teachers, at which time the Retiring Vice President of Section B, George B. Pegram, will deliver an address. There will also be an address by the President of the American Physical Society, H. M. Randall, on "The Spectroscopy of the Far Infrared," and one by Professor G. Breit of the University of Wisconsin. The dinner will be held on Wednesday, December 29.

General Rules Relating to Papers

Only those titles of papers shall be listed on the preliminary program of a meeting of the Society for which abstracts ready for publication are in the hands of the Secretary.

On December 28, 1936, the Society voted that:

No papers may be accepted for presentation at any meeting of the Society subsequent to the closing date stated in the printed call for that meeting.

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program. (A paper presented by two or more authors is assigned to the first named author.)

All supplementary papers will be grouped according to subject matter and will be called for at their appropriate sessions only, these sessions to be designated on the program. The presiding officer may assign a reduced time to these papers or may in his discretion call for them to be read by title only.

Except by special vote of the Society, the maximum allowance of time for the presentation of a paper shall be ten minutes. The presiding officer shall enforce this rule.

Titles and abstracts of the papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction the abstracts will be published in an early number of the *Physical Review*. Authors should send corrections to the Publications Manager, The American Institute of Physics Incorporated, 175 Fifth Avenue, New York, N. Y.

Other meetings for the current season are as follows:

218. December 28–30, 1937. Annual Meeting. Indianapolis, Indiana.
219. February, 1938. New York, N. Y.
220. April, 1938. Washington, D. C.

PAUL KIRKPATRICK
Local Secretary for the Pacific Coast
Stanford University, California.

December 2, 1937.

DEC 3 1937

PROGRAM

FRIDAY MORNING, 9:30 O'CLOCK

Room 372

1. Positive-Point to Plane Discharge in Air at Atmospheric Pressure. ARTHUR F. KIP, *University of California.*—Investigations are being carried out on current-voltage characteristics of positive-point to plane discharge. All currents start *abruptly* and increase linearly with voltage in the lower part of the $I-V$ curve. Lowering the voltage decreases the current until voltage reaches the critical voltage V_c, at which point the current cuts off. It is shown that at any $V>V_c$ an electron appearing in the gap is sufficient to start steady corona. The initial current jump is found to depend on gap geometry and excess of voltage over V_c. The minimum steady current which will flow is a function of gap geometry only, decreasing as gap distance is increased. A radioactive source placed near the point when V is slightly less than V_c gives Geiger counter action. The maximum current flowing in this case fits the straight line $I-V$ curve extrapolated below V_c. With radioactive source, steady current onset and minimum steady current are found to coincide. Initial $I-V$ slopes are expressed as a resistance which is found to increase linearly with the gap and to account for approximately 1 percent of the total voltage drop in the gap. Extrapolation of resistance to zero resistance gives the minimum gap at which stable corona will flow.

2. Ionization, Negative Ion Formation, and Recombination in the Ionosphere. NORRIS E. BRADBURY, *Stanford University.*—The ionization in the ionosphere is discussed in the light of present theories of recombination and negative ion formation. It is suggested that the E and F_1 regions are formed as the result of the absorption of special bands of solar radiation and that negative ion formation is the predominant process in these regions. A sufficient number of electrons exists, however, to cause the reflection of electromagnetic waves. The F_2 region is probably not due to the absorption of any special band of solar radiation but owes its formation to the preponderance at this elevation of electron-positive ion recombination over negative ion formation during the day. The characteristics of the E and F_1 regions are discussed quantitatively and compared with experimental observations. A qualitative discussion is given for the F_2 region since it seems probable that significant changes in level and density take place at these elevations.

3. The Effect of Cathode Material on the Second Townsend Coefficient for Ionization by Collision in Pure and Contaminated N_2 Gas. W. E. BOWLS, *University of California (Introduced by Leonard B. Loeb).*—A study of the Townsend coefficients α and β and the ratio $\beta/\alpha=\gamma$ for ionization by photoelectrons in a plane parallel gap in N_2 as a function of the ratio of field strength x to pressure p has been carried out. Electrodes of Pt, Hg, and Na were used with contamination of the N_2 by Hg vapor and Na vapor and possibly H_2 from the Na when such electrodes were used. The results of previous investigators were duplicated when Hg contamination was present. The results show α/p as a function of x/p to be materially lower with pure N_2 than when Hg and especially Na contamination is present. This can be ascribed to ionization of Hg and/or Na and H by the electrons and/or metastable status of N_2. The values of $\beta/\alpha=\gamma$ for Pt show a sharp peak rising at $x/p=60$, then falling sharply, eventually to rise again. The peak is ascribed to the action of N_2 radiation or metastable molecules on the Pt surface. The later rise is due to a secondary electron liberation by positive ion impact. The presence of Hg and Na or H_2 destroys the radiation mechanism. With Na, enough of the high energy radiation gets through to cause a small peak of $\beta/\alpha=\gamma$ at a higher x/p than for Pt.

4. Sparking Potential Measurements in Nitrogen and Argon for Platinum and Sodium Cathodes. FLORENCE EHRENKRANZ, *University of California (Introduced by Leonard B. Loeb).*—Curves were obtained for sparking potentials between fixed plane parallel electrodes in pure mercury-free argon and nitrogen with Pt and Na cathodes as a function of the pressure times the plate separation. The argon measurements covered a $p\cdot\delta$ range of 1 to 240 (mm×cm) for pressures from 1.6 to 400 mm. The A-Pt sparking potentials agree very closely with Penning's A-Fe values. For Na cathodes they are six percent lower than for Pt except near the minimum. The minimum value for Pt is 210 volts, for Na 97 volts. Predischarge currents were less than 10^{-9} amperes for Pt and Na cathodes. For N_2 $p\cdot\delta$ ranged from 1 to 380 (mm×cm). Sparking potential values for Na cathodes are twenty percent lower than for Pt except near the minimum where the difference is slightly greater. The minimum for Pt is 276 volts and for Na 200 volts. Predischarge currents ranging from 360μA at a $p\cdot\delta$ of 360 to 15μA at a $p\cdot\delta$ of 10 were observed for Na cathodes. Pt cathodes with pure nitrogen gave predischarge currents less than 10^{-9} amperes. Spectroscopic traces of Hg gave random predischarge currents varying from microamperes to 10^{-9} amperes.

5. Carrier Mobility Spectra of Liquids Electrified by Bubbling. SEVILLE CHAPMAN, *University of California.*—Data previously reported[1] on the electrification of aqueous solutions by spraying, investigated with an Erikson mobility tube under conditions of high resolving power, have been extended to bubbling, which gives more homogeneous groups of carriers. Distilled water gives sharply defined peaks on current-mobility curves corresponding to groups at mobilities 1.9, 1.1, 0.4 cm/sec. per volt/cm for negatives; 1.1 and 0.4 for positives. No carriers are produced with mobilities less than 0.1. Depending on the size of the bubbling capillary, the ratio of the total amount of positive

electrification to negative varies from 1 : 2 (small capillary) to 1 : 100 (12 mm tubing), due to change in bubbling mechanism. Using high humidity air blasts gives less fast carriers, more slow carriers, and produces heterogeneous spreads of mobilities. Addition of salts to water favors production of slow carriers at the expense of fast ones, the curves degenerating to continuous distributions of mobilities from mobilities roughly 0.5 to 0.01. Medium concentrations (10^{-4} molal) produce more total electrification than distilled water, high concentrations (1 molal) less. Various concentrations of sodium stearate and sugar solutions give curves indicating significant surface tension effects. Results are interpreted on the basis of the electrical double layer theory of liquid surfaces.

[1] Seville Chapman, Phys. Rev. **52**, 184 (1937).

6. Relativistic Spin-Orbit Coupling in Nuclei. S. M. DANCOFF AND P. MORRISON, *University of California (Introduced by Professor J. R. Oppenheimer)*.—One can obtain a qualitatively correct account of nuclear magnetic moments by ascribing them: (1) to the intrinsic magnetic moment of the unpaired proton or neutron, (2) to the magnetic moment of a uniformly-rotating charged "drop," (3) to the relative orientation of these moments as determined by the relativistic Thomas precession of the spin. We have tried to generalize Thomas' result to this model, in order to estimate doublet splitting and the rate of interconversion of spin and rotational angular momenta.

7. Production of Pairs by Fast Electrons. W. E. LAMB, JR., *University of California*, AND A. J. F. SIEGERT, *Stanford University (Introduced by J. R. Oppenheimer)*.—The production of pairs by the impact of fast electrons on nuclei may be understood as the sum of two effects: (1) the pair production in the nuclear field by virtual quanta of the electron's field; and (2) the internal conversion of the radiation field of the deflected electron. Elementary calculation gives correctly the dominant term for the former effect, but gives an incorrect result for the latter. To elucidate this point the internal conversion formulae are derived for multipole radiation of high order; and the problem is also treated in the rest coordinate system of the electron. It is shown that for (2) the terms in $\ln^2 E/mc^2$ and $\ln^2 E/mc^2$ (E is the primary energy) vanish.

8. On the Dynaton Theory of Nuclear Forces. R. SERBER, *University of California*.—Yukawa has suggested that the range and magnitude of nuclear forces might be simply understood if it be supposed that neutrons and protons can exchange particles, of charge $\pm e$ and mass μ such that $\hbar/\mu c$ is approximately the range of nuclear forces. Interest in Yukawa's suggestion has recently been revived by cosmic-ray evidence which indicates the existence of charged particles of intermediate mass. Closer examination, however, using the usual methods of quantum field theory, shows that on this basis it is not possible to obtain a satisfactory description of nuclear forces: (1) The force between neutron and proton in a state symmetric in their coordinates turns out to be repulsive rather than attractive; (2) the forces between like particles are only a few percent of the proton-neutron forces; (3) the spin dependence of the forces is not given correctly; (4) there is no resultant magnetic moment for neutron or proton. The difficulties (3) and (4) may be remedied only by further *ad hoc* assumptions. The correct spin dependence of the proton-neutron forces can be obtained by including, in addition to the scalar field originally suggested by Yukawa, a six vector field, and the magnetic moment by choosing a suitable coupling of these fields and the electromagnetic field. Objections (1) and (2) seem intrinsic.

FRIDAY AFTERNOON, 1:30 O'CLOCK

Room 372

9. Neutron Produced Activities in Uranium. PHILIP ABELSON, *Radiation Laboratory, University of California*.—Activation of uranium with neutrons leads to an extraordinary number of artificially produced radioactivities. The extensive work of Meitner, Hahn and Strassmann* has been repeated in this laboratory and, for the most part, verified. Sign of charge of emitted particles has been checked in a Wilson chamber and found in all cases to be negative. In the main the half lives given by the German workers have been confirmed. It has further been verified that at least two separate chains of β-decays exist, both of which can be obtained from uranium activated with thermal neutrons. In addition a new period of 17 hours half-life has been found. With the possibility in mind that the chain of β-decays may be followed by α-decay, α-particle emission from the neutron activated uranium was investigated. Placing activated material against the ionization chamber of the linear amplifier within five minutes after completion of activation produced no observable effects. It was concluded that α-radioactive isotopes of half-lives less than 1000 years are not present in amounts comparable to the β-active isotopes.

* Meitner, Hahn and Strassmann, Zeits. f. Physik **106**, 249 (1937).

10. Neutrons from Boron plus Deuterons. H. STAUB* AND W. E. STEPHENS, *W. K. Kellogg Radiation Laboratory, California Institute of Technology*.—The energy distribution of neutrons from the disintegration of boron by 1 MV deuterons has been measured by the method of α-recoils in a helium-filled high pressure cloud chamber whose stopping power was calibrated with thorium C′ α-particles. The curve is very similar to that of Bonner and Brubaker,[1] but the energy scale should be somewhat more accurate due to the stopping power calibration. Preliminary calculations give disintegration energies of $Q_0 = 13.65 \pm 0.2$ MV,

$Q_1 = 9.20 \pm 0.2$ MV, $Q_2 = 6.15 \pm 0.2$ MV, and $Q_3 = 3.90 \pm 0.2$ MV. The relative intensities are about 1 : 2 : 1 : 3.

* International Exchange Fellow.
[1] Bonner and Brubaker, Phys. Rev. **50**, 308 (1936).

11. Nuclear Transformations Produced in Zinc by Alpha-Particle Bombardment. W. B. MANN, *Radiation Laboratory, University of California.*—Zinc has been bombarded by 15 Mev alpha-particles and the consequent radioactivity investigated. Two activities, having half-lives equal to 20 minutes and 41 hours, may be assigned respectively to Ga^{70} and the new isotope Ga^{67}. β-ray absorption measurement gives, respectively, maximum energies of about 2.6 and 1.2 Mev.

12. Neutrons from Lithium plus Deuterons. WILLIAM E. STEPHENS, *W. K. Kellogg Radiation Laboratory, California Institute of Technology.*—The measurements of Bonner and Brubaker[1] on the energy distribution of neutrons from the disintegration of lithium by deuterons have been repeated by using α-recoils in a helium filled cloud chamber. Two distinct groups were found giving disintegration energies of 15.1 ± 0.2 Mev and 12.0 ± 0.2 Mev. These groups are attributed to the formation of Be^8 in a normal state and an excited state of about 3 Mev with a width at half maximum of the order of 1 Mev. The formation of Be^8 together with the formation of He^5 are probably the most important if not the exclusive modes of disintegration in this reaction.

[1] Bonner and Brubaker, Phys. Rev. **47**, 973 (1935).

13. Radioactive Isotopes of Cu, Zn, Ga and Ge. R. SAGANE, *Radiation Laboratory, University of California.*—Neutron bombardments, both fast and slow, on Cu, Zn, Ga and Ge were made. By studying the decay curves and relative intensities of the activity obtained for each isotope, the mass numbers for those radioactive isotopes were proposed. A study for β-rays and γ-rays was also made. For neutron loss process or $n-2n$ reaction, Cu needs more than 12 Mev, while for Zn, Ga, and Ge, less than 8 Mev is sufficient. It is hoped to give these values more accurately. The general results are as follows.

ELEMENT	SIGN	T	β AL$\frac{1}{4}$	γ PB$\frac{1}{4}$
Cu^{62}	+	10^m	16×10^{-3} inch	6mm
Cu^{64}	+ −	12.8^h	28×10^{-3}	yes
Cu^{66}	−	5^m	—	—
Zn^{63}	+	37^m	27×10^{-3}	yes
Zn^{69}	−	57^m	9×10^{-3}	—
Ga^{68}	+	66^m	15×10^{-3}	4mm
Ga^{70}	−	20^m	15×10^{-3}	no
Ga^{72}	−	14.1^h	16×10^{-3}	8mm
Ge^{69}	+	30^m	16×10^{-3}	yes
Ge^{71}	+	26^h	10×10^{-3}	yes
Ge^{75}	−	80^m	8×10^{-3}	yes
Ge^{77}	−	7^h	—	—

14. The Gamma-Radiation from Boron Bombarded by Protons. W. A. FOWLER, E. R. GAERTTNER* AND C. C. LAURITSEN, *W. K. Kellogg Radiation Laboratory, California Institute of Technology.*—By use of a method which has been described previously,[1] we have determined the distribution in energy of pairs and recoil electrons ejected from lead and carbon laminae by the gamma-radiation from boron bombarded by protons. Both the pair and electron distributions indicate three prominent gamma-ray lines at $4.4 \pm .3$ Mev, $11.8 \pm .5$ Mev and $16.6 \pm .6$ Mev with relative intensities of 1 : 1 : 1/6, respectively.

* National Research Fellow.
[1] Delsasso, Fowler and Lauritsen, Phys. Rev. **51**, 391 (1937).

15. On the Disintegration of Nitrogen by Neutrons; Further Experiments in a Low Pressure Cloud Chamber. FRANZ N. D. KURIE AND MARTIN KAMEN, *Radiation Laboratory, University of California.*—Measurements on the disintegration of nitrogen by neutrons were obtained in a cloud chamber filled with nitrogen at reduced pressure so that the stopping power was of the order 0.3. The neutrons arose from the bombardment of beryllium with 5.5 MV deuterons in the Berkeley cyclotron. An attempt was made to collimate the neutrons by providing a path for them between the cyclotron and the cloud chamber in the form of a closed brass tube sunk in the 34-inch thick water tanks which surround the cyclotron. The total material in this path was one inch of brass, $\frac{1}{8}$-inch of iron, $\frac{1}{4}$-inch of water and 7 feet of air. A very good yield of disintegrations was obtained with this arrangement. The data were correlated by plotting the total energy appearing as kinetic energy of the products of the disintegration against the energy of the captured neutron. The methods of obtaining these numerical data have been described before.[1] The conclusion is reached that the uncertainties in the stopping power of the gas, the range energy relation for boron together with the large straggling of the range of the heavy particle render it impossible by this method to examine this disintegration in any more detail than has already been done.

[1] Kurie, Phys. Rev. **47**, 97 (1935); **49**, 208 (1936).

16. Cloud Chamber Studies in the Cyclotron Magnetic Field. LUIS W. ALVAREZ AND WILLIAM M. BROBECK, *Radiation Laboratory, University of California.*—A cloud chamber was constructed to be operated in the 6 to 8 kilo-oersted magnetic field adjacent to the cyclotron target chamber. Attempts to increase the field to about 12 ko by placing blocks of iron above and below the chamber were frustrated by a resulting drop in the deuteron energy from 5.5 to 2.5 MV. Photographs were taken with a single camera, through a mirror at 45°. A thin window in the wall of the chamber allowed disintegration products from deuteron reactions to be photographed in the forward direction. Most of the work, however, was done on neutron reactions, by using the high energy neutrons from Li+D. The chamber was filled at various times with helium, argon, oxygen, and air, and a target of Be was often cemented to the inside wall of the chamber, about 2 cm from the neutron source. No heavy particles of definite negative sign were observed. Many positively charged particles were observed which had a range in argon from 3 to 10 times that to be expected from their curvature if one assumed them to be protons. These tracks decreased in relative abundance when the chamber was made more shallow, so they were probably protons making an angle with the plane of the chamber.

17. Focusing Actions in the Cyclotron. ROBERT R. WILSON, *University of California.*—A qualitative study of the focusing of ions being accelerated in the cyclotron is made on the basis of electric and magnetic field measurements. Ion paths are calculated by a step by step process of integration. At small path radius r, only the electrostatic action is effective and is a defocusing which causes the ions to move away from the central plane between magnet pole faces; thus ions are lost, and the number of these is found to decrease with d/h, the ratio of electrode height to electrode separation. At larger r, the electrostatic effect, which decreases with r^3, would cause the ions to oscillate slowly about the central plane with increasing amplitude. However, before these oscillations can occur the magnetic focusing, which increases rapidly with r, predominates and causes the ions to oscillate with decreasing amplitudes that determine the beam height and are proportional to $(r\varphi)^{-\frac{1}{2}}$ where φ is the angle made by the direction of magnetic field with the vertical one cm above the median plane. The heights of the beam, obtained at various r for the cyclotron at Berkeley by measuring the radioactivity induced in a probe, agree very well with values calculated from the theory.

SATURDAY MORNING, 9:30 O'CLOCK

Room 372

18. Absorption Spectra of Diatomic Fluorides in the Carbon-Tube Furnace. F. A. JENKINS AND G. D. ROCHESTER, *University of California.*—The spectra of the fluorides of Be, Zn, Cd, Al, Ti, Sn, Pb, Sb, Bi, Cr, Mn, and Fe vaporized at temperatures between 1000 and 2000°C have been examined with a small quartz spectrograph in the wave-length region 5000 to 2000A. Certain modifications with regard to the heat shielding in the carbon-tube furnace recently described[1] have been made, and these give a considerable improvement on the efficiency there reported. Several new band systems are found. Of these, SnF, ZnF, MnF and PbF have been photographed in the first order of the 21-ft. grating (dispersion 1.32A/mm). Measurements of SnF show five doublet band systems and two continua. The Sn isotope effect is well resolved. In addition to the fluorides, the metals Cu, Mn, Al and Sn have been tried, but gave no molecular spectra. With AgCl two new band systems and a continuum, all lying below λ2500, have been discovered, and their characteristics agree excellently with predictions of Mulliken.[2]

[1] Phys. Rev. **52**, 1135 (1937).
[2] Phys. Rev. **51**, 310 (1937).

19. Resonance Broadening of Spectral Lines. W. V. HOUSTON, *California Institute of Technology.*—The method of Furssow and Wlassow[1] for computing the broadening of spectral lines, due to the interaction of the excited atom with unexcited atoms of the same kind, seems to have the most conceptual clarity of any yet suggested. By using this method it is possible to compute the broadening when the fine structure is not neglected. The result can be expressed in terms of the strength of the line, as defined by Condon and Shortley, and shows that the broadening is the same for all members of a close multiplet. This is in agreement with the recent results of Lloyd, although the absolute value of the effect is, as with other computations, considerably smaller than the observed.

[1] Phys. Zeits. Sowjetunion **10**, 378 (1936).

20. Detection of Cocaine-HCl in Cerebrospinal Fluid by Spectroscopic Analysis. L. A. STRAIT AND R. B. AIRD, *University of California.*—It was desired to determine the approximate amount of a narcotic in cerebrospinal fluid in connection with a neurological problem. Cocaine-HCl was chosen because it is soluble in body-fluid and has characteristic strong absorption bands in the ultraviolet region of the spectrum:[1] one, with peak at 2700A, log $\epsilon \doteq 3.0$ and another with peak at 2300A, log $\epsilon \doteq 4.0$. The experimental arrangement is the same as that used by the first author in determining the characteristic u.v. absorption of vitamin E.[2] Normal cerebrospinal fluid (C.S.F.) is opaque in the region from 2800A to 2300A, making it impossible to detect the spectrum of cocaine-HCl in normal C.S.F. A simple process has been developed which makes the C.S.F. transparent to the desired degree. Simple additional manipulations permit the extraction from C.S.F. of cocaine-HCl. Concentrations of cocaine-HCl of the order of 1/100 g percent (1 part in 10,000) clearly indicate both characteristic curves of cocaine-HCl. A concentration of 1/300 g percent displays the absorption of the band only at 2300A. Concentrations up to 1/1000 g percent (1 part in 100,000) show detectable but faint absorption. Quantitative measurements can be made by means of photographic intensitometry.[2]

[1] Castille, Bull. Acad. Roy. Méd. Belg. **5**, 193 (1925); Dobbie and Fox, J. Chem. Soc. **103**, 1193 (1913).
[2] H. M. Evans, Oliver E. Emerson, and Gladys A. Emerson, J. Biol. Chem. **113**, 319–332 (1936).

21. High Pressure Capillary Lamps. C. BOL, *Stanford University, California.*—Demonstrations will be given of the later developments of high pressure mercury capillary lamps. The cooling liquid which flows around the quartz capillary is put under high hydraulic pressure, up to 1000 atmospheres. Under these conditions arc voltages of 2500 volts per cm and an input of about 2 kilowatts bring the light to a strong, white brilliancy. The ultraviolet portion becomes more and more absorbed, while the percentage of red increases. Demonstrations will be given also at lower pressures with a water-cooled lamp. When most of the visible light has been filtered out, the ultraviolet rays will very effectively light up a collection of fluorescent minerals.

22. Rotational Energy Distribution of OH Molecules from the λ3064 Band. ELISABETH REED LYMAN AND F. A. JENKINS, *University of California.*—The 0,0 OH band,

λ3064, excited in both electrode and electrodeless discharge tubes, was photographed in the second order of the 21-foot concave grating. Log I/i is plotted against the corresponding rotational term values where I is the photometrically measured intensity of lines and i, the theoretical intensity factor. Assuming thermal equilibrium, curves through the plotted points should be straight lines. All of the curves from the discharge tube spectra deviate from straight lines at high quantum numbers, the deviations indicating more molecules than expected present in high levels. The lower the water vapor pressure, the lower average rotational energy, but none of the curves show thermal equilibrium. Addition of small amounts of helium or argon (1 or 2 cm) does not alter these effects although some evidence was found that addition of helium reduced the rotational energy at very low current densities. Absence of thermal equilibrium prohibits the calculation of the temperature of the emitting gas in discharge tubes. Measurements of the band excited in the oxy-hydrogen flame and in the copper arc show thermal distributions of intensities from which temperatures of 3275°K and 6350°K, respectively, are calculated.

23. The Mechanism of Corona Discharge. G. W. TRICHEL, *University of California* (*Introduced by Leonard B. Loeb*).—A study has been made of the mechanism of corona discharge between a point and plane in air at atmospheric pressure. Signals produced in a radio set by corona discharge have been compared with the voltages across a resistance in series with the point by means of a cathode-ray oscillograph. In the case of negative point coronas there appears to be a definite relation between the wave shapes of voltages obtained by these two methods. Radio pickup has been used to study certain phases of the positive point corona which does not produce any oscillograph pattern when the voltage across a series resistor is used. Signals obtained by radio pickup have been applied to a high speed impulse counter of the Wyn-Williams type. A study of the counting rate as a function of corona current and voltage, using various voltage sensitivities of the radio set, appears to give information about the number and magnitude of the electron avalanches comprising the corona discharge.

24. The Secondary Nature of Cosmic-Ray Effects in the Lower Atmosphere. I. S. BOWEN, R. A. MILLIKAN, AND H. VICTOR NEHER, *California Institute of Technology*. —(*a*) The intensity of latitude sensitive cosmic rays as measured by an electroscope placed just outside the atmosphere has been determined. (*b*) The ionization due to incoming electrons of 10 billion ev energy in this same electroscope placed 1/20th of an atmosphere beneath the top is found to be 13 times that outside. (*c*) Electrons do not become penetrating by virtue of high energies even up to 17 billion ev. (*d*) Neither protons nor other penetrating particles of any sort enter the atmosphere in significant numbers from outside the atmosphere. (*e*) The observed penetrating particles and all other cosmic-ray effects, latitude sensitive and non-latitude sensitive, found in the lower atmosphere are practically all secondary effects—splashes from the absorption of electrons, or photons, or both taking place in the outer layers of the atmosphere.

25. Nuclear Disintegrations Produced by Cosmic Rays. ROBERT B. BRODE AND MERLE A. STARR, *University of California*.—The appearance of a heavy ionizing particle in a Wilson cloud chamber photograph of cosmic rays is not a very rare event. In 20,500 photographs, 215 heavy particles were observed. In ten cases the photograph showed the heavy particle as originating from a disintegration in either the wall of the chamber or in a lead plate in the center of the chamber. Where the disintegration was produced before the expansion, only the heavy tracks were visible, but in other cases tracks of the density of electron tracks were found radiating from the disintegration center. Other time coincident shower tracks are also visible in the chamber, indicating that these disintegrations are associated with cosmic-ray showers. The ejection of a number of heavy particles from a single nucleus can be interpreted as an "evaporation" of particles from a highly excited nucleus.

26. New Techniques in the Use of Geiger Counters. H. V. NEHER AND W. H. PICKERING, *California Institute of Technology*.—A modification of the high speed counter circuit developed by Neher and Harper[1] permits the cylinder of the counter to be grounded. This has advantages in eliminating shielding and in using counters under special conditions when it is desirable to have the cylinder at ground potential. There is an advantage also in the fact that the normal potential drop across the first radio tube is much lower than in the previous circuit. The resistances used are in general lower and the performance better than before. Either a positive or negative pulse is obtainable to operate the next stage. To actuate a mechanical recorder a new type of extinguishing circuit has been applied to the argon-filled 885 tubes. Such a circuit eliminates the necessity of breaking the plate current of the tube mechanically, hence improves reliability. Oscillograph figures indicate a resolving time of 10^{-3} to 10^{-2} sec., depending on the impedance of the mechanical counter. These new circuits are applied to four Geiger-Muller counters 4 ft. long and 6 inches in diameter counting coincidences due to cosmic rays.

[1] Phys. Rev. **49**, 940 (1936).

27. Evidence for a Cosmic-Ray Particle of Intermediate Mass. DALE R. CORSON AND ROBERT B. BRODE, *University of California*.—A cloud chamber photograph of a positive, heavily ionizing cosmic-ray particle, with a measurable deflection in a magnetic field, has been obtained. The expansion was delayed 0.5 second to facilitate measurement of ionization. The $H\rho = 3\times10^5$, with about 265 droplets (at NTP) per cm, contrasted with an average of 55 droplets per cm for an electron of $H\rho = 4\times10^3$. Assuming that ionization is inversely proportional to the square of the velocity, one calculates a rest mass 350 times the rest mass of the electron. However, if one adopts the data of Williams and Terroux[1] in which electrons in this energy range

were found to ionize inversely as the 1.1 power of the velocity, one calculates a mass of about 700 times the rest mass of the electron. It is estimated that the limit of error in the measurement of the radius of curvature and in the number of droplets per cm is less than 20 percent. The length of the track in the chamber, 15 cm, eliminates the possibility of the particle being a proton.

[1] Williams and Terroux, Proc. Roy. Soc. **A125**, 289 (1930).

28. The Production of Cosmic-Ray Showers at Great Depths. W. H. PICKERING, *California Institute of Technology.*—Experiments have been performed with Geiger counters under various depths of water up to about 30 meters. These show definitely the existence of showers consisting of at least three particles under such thicknesses of water. Down to 30 meters the ratio of the number of showers to the number of vertical coincidences remains approximately the same as its sea level value. The effect of lead on the shower counting rate below sea level has been investigated and no appreciable change due to the lead obtained. This result, however, is complicated by the fact that a heavily reinforced layer of concrete about two feet thick was immediately above the apparatus. An additional experiment confirms the result that the shower counting rate decreases at the same rate as the counting rate for vertical coincidences below sea level. This was performed by finding the number of showers emerging from a 1.6 cm lead plate as a function of zenith angle, and comparing it with the corresponding distribution about the zenith of the single rays. Except for a small correction for the different geometry in the two cases, the two distribution functions appear to be identical.

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member one only of these will be assigned a place on the regular program while the others will be placed in a supplementary program to be called for if time permits.

Papers received after the program has been printed will be placed in the supplementary program.

The papers in the supplementary program may be called for only at the session indicated.

29. Theory of Neutron-Deuteron Impacts.[1] W. E. LAMB, JR. AND R. SERBER, *University of California.*—A method has been developed for the treatment of such three-body problems as the collision of slow neutrons with deuterons, in which the range of forces is treated as negligible in comparison to the size of the deuteron. In this limit, the integral equation which is equivalent to the wave equation and its boundary conditions expresses the wave function at all points of space in terms of its value just in regions in which two particles are within the range of their forces. One has then to guess the form of the wave function in these regions, and may check this by calculating the wave function from the integral equation. One is guided in this choice by the behavior of the wave function in the theory of the deuteron and by an exact solution which we have obtained of the scattering problem for a neutron in the field of a fixed neutron and proton.

[1] To be called for after paper No. 8.

30. Search for Short-Lived Radioelements.[1] LUIS W. ALVAREZ, *Radiation Laboratory, University of California.*—The failure to observe any positron-radioactive elements higher in the periodic system than the rare earths has been puzzling, since many such isotopes should be formed by the reaction: $(n-2n)$. The experimental observation that electron capture and positron emission are about equally probable for $Z=23$, coupled with the theory, which predicts the former process to predominate for large Z, suggested the possibility that the expected positron emitters have their half lives so reduced by the alternate decay process that they have escaped detection. A holder was arranged to transport targets from the immediate vicinity of a lithium neutron source to a Lauritsen type electroscope in 0.3 second, and at the same time turn off the deuteron beam. The electroscope and observer were protected from neutrons during the bombardment by a meter of water. No short life products were found in Pt, Au, Hg, Tl, and Pb. Several short periods (1 to 10 sec.) in the light elements were verified, and in some cases, the decay curves were followed by means of a kymograph recorder controlled with a telegraph key.

[1] To be called for after paper No. 17.

31. On Some Operating Characteristics of a Cloud Chamber Designed for Use Through a Range of Pressures.[1] FRANZ N. D. KURIE, *Radiation Laboratory, University of California.*—A cloud chamber is described which was designed for operating at pressures ranging from the vapor pressure of the condensant to several atmospheres. The chamber follows somewhat the designs of Petrova and Joliot in that the expansion is made by an auxiliary piston so that the speed of the expansion is at the disposal of the operator and to a large degree independent of the pressure in the region where the tracks are formed. A very interesting and useful property of this chamber is the fact that its sensitive time can be varied. By reducing the driving pressure and increasing the expansion stroke this time can be made of the order of half a second. The chamber can be operated ten times a minute and since its volume is over a liter its sensitivity is as great as an ordinary linear amplifier. Another property is frequently a source of annoyance; this is the phenomenon of "streaming" or "curtaining." Under some conditions the tracks appear to have vertical curtains attached to them. A possible explanation of this effect is discussed and means of obviating it are mentioned. Methods of "keying" a cyclotron in synchronism with the chamber will be considered.

[1] To be called for after paper No. 17.